# **GEOASIA Bulletin No.8**

## ALL SOILS ALL STATES ALL ROUND GEO-ANALYSIS INTEGRATION



For finding soil deformation and collapse in sandy, intermediate and clayey soils, and for static or dynamic interests Issued August 22, 2014 Edited by *GEOASIA* Research Society Office Furo-cho, Chikusa-ku, Nagoya, 464-8603, Japan TEL: +81-(0)52-789-3834 FAX: +81-(0)52-789-3836 E-mail: office@geoasia.jp URL: http://www.geoasia.jp

### Message from the Society President

Before writing this Message, I began by rereading the one I wrote three years ago (Bulletin No. 5, Japanese edition, August, 2011). In it, I was wondering whether the shaking of public trust in science that followed the earthquake disaster of that year might not apply to geomechanics as much as to seismology. If that was the case, I was placing my expectations on further advances in research from the **GEOASIA** Research Society.

As an immediate response to the 2011 disaster, Osamu Kusakabe, who was president of the Japanese Geotechnical Society (JGS) at the time, set up three special presidential research committees, one of which was for "the Mechanisms of Earthquake-Induced Large Ground Deformations (Seismic and Post-seismic)." As I implied in my 2011 Message, there was a clear call here for groundbreaking advances in the geo-related disciplines of science and technology, leaving no room for clinging to inherited

frameworks. While I serve something of a figurehead function as chair of this committee, many members of the *GEOASIA* Research Society, under head director Toshihiro Noda, have been actively involved with the practical work at public JGS sites, collaborating with upcoming researchers in the industrial, administrative and academic sectors in the promotion of shared research that will lead through its numerous results to the required academic advances. The final report of the committee was presented to a special JGS symposium on the earthquake disaster in May, 2014. Further findings will be reported at the "Grants-in-Aid for Scientific Research(S)" presentation event preceding the 2014 General Meeting of the *GEOASIA* Research Society.

Which of all these research tasks performed by members of our Society can be singled out as contributing to "groundbreaking advances"? I can only mention a handful of the achievements here, and only in the roughest of outlines, but let me pick three that seem noteworthy to me.

(1) As a result of trying to convert all foundation problems into "integrations of (incremental) equation of motion," a notion has arisen that certain problems that are inherently unsolvable can be reliably and stably dealt with by resorting to equations for "equilibrium of forces" or "quasi-static processes." One member of this society was once bold to say that "a 'bearing capacity problem' is essentially one that has to be solved using an equation of motion, and not in terms of 'limit equilibrium.' For my part, I have illustrated this before now with the observation that "a ground rumbles before it collapses." The point that it has not always been the regular practice to change to equation of motion for solving an earthquake problem is of vital importance. Only with this dynamic analysis does it become possible to treat the time taken in the unfolding of forces as a reality, which not only allows the pre-, during- and post- stages of the event to be treated sequentially, but also contributes valuably to attempts to "create earthquakes" through simulations of effects such as Riedel shears and flower structures.

(2) A major advance is implied in the transition from a saturated soil mechanics to a mechanics for a three-phase unsaturated soil system. In a problem of initial values and boundary values, researchers who had previously seen cases of groundwater being sucked up into a river levee after an earthquake were startled by photographs showing



that the same kind of phenomenon had occurred in a road embankment. The idea that unsaturated soil was a problem "confined to a tiny topsoil layer" and therefore of no wider significance turned out to be completely wrong. The deep-seated slides in the Iwate Miyagi earthquake in 2008 all occurred in unsaturated soils. Further, soil samples collected from the shear zones of plate boundary earthquakes are all reported to have been unsaturated.

(3) Advances are also important in the formulation of the elastoplastic constitutive equation. The Cam-clay model is made up of terms for the Roscoe surface and the elastic wall (the hypo-elastic subtype of a nonlinear isotropic Hooke's law). But while the Roscoe surface can be obtained purely and factually from experimental data, the elastic wall component has always been firmly tied to the constraints of the isotropic Hooke's law from which it derives. That is to say, it is an introduced element with little explanatory power to account for experimental results. In the alternative "hyperelastic model" proposed by Professor Toshihiro Noda, the effective stress path on the isovolumetric recharging surface p'-q rises up obliquely on the outer side, which not only allows a straightforward explanation to be given for the increase in shear rigidity without any need to increase the number of parameters involved, but has also made it possible to arrive at an extremely good representation of the cyclic mobility of the sand. This was an achievement that took my breath away when I first saw it last year (2013), but certainly there is no reason why improvements to the elastoplastic constitutive equation should remain as "mere" improvements. (Let me add in passing that the research dome by Associate Professor Shotaro Yamada reminded me of rigid-plasticity calculations of the past in which the problem of calculating the drained bearing capacity of sand was known as the "finding of inhomogeneities in the von Mises stress distribution" while the term "non-associated flow rule" was not used.) It is a fact that dramatic advances are now being made in constitutive equation research, including the area of anisotropy. The reconcilement of theory with experiment is a major case in point and it is gratifying to see the progress that has been made here not only through the incorporation of the concept of a super loading yield surface into the Cam-clay model, but now also through the inclusion of the Drucker-Prager model as well.

Let us also work hard in the year ahead to ensure that the President's Message for 2015 has more growth to report in the diffusion of the *GEOASIA* Research Society's technology and in its training activities for society members. I appeal for members' continuing cooperation in this.

Akira Asaoka,

Senior research advisor, the Association for the Development of Earthquake Prediction (reg. foundation); Emeritus professor, Nagoya University

**Research Results (***From Overcoming the Great East Japan Earthquake: A Collection of Papers from a Special Symposium held by the Japanese Geotechnical Society***)** 

This edition of the Bulletin introduces a few of the research results obtained using GEOASIA technology that were presented at the special symposium "Overcoming the Great East Japan Earthquake" (May 14 and 15, 2014) held by the Japanese Geotechnical Society Research Committee on the Mechanisms of Large Ground Deformations (chairman Akira Asaoka).

## (1) Increased liquefaction damage in Urayasu city as the result of a surface wave generated from an irregular ground boundary

A model of the affected ground in Urayasu city was created from site borings and the results of laboratory tests and was then used as input for a seismic response analysis, allowing observations to be made on the causal factors for the extensive non-uniform liquefaction damage that occurred there after the Great East Japan Earthquake. In addition to the presence of a layer of soft clay beneath the liquefaction layer which led to an amplification of the long-period range of the seismic wave, a slope in the foundation also meant that the surface wave was generated from irregular boundaries, setting up a comparatively strong and persistent tremor that triggered and magnified the liquefaction damege.



Figure 1. Occurrence of non-uniform deformation (Distribution of shear strains 200 sec. after start of earthquake)



Figure 2. Surface wave caused by areas of inclination in the ground (Velocity vectors 92 sec. after start of earthquake)

# (2) Seismic and post-seismic deformation behavior in mudstone embankments under different degrees of compaction and at different stages of slaking

Analyses of seismic responses were performed on parameters obtained from the results of undrained triaxial tests carried out on mudstone samples at varying stages of slaking. At higher degrees of compaction there was a rise in the overconsolidation ratio at lower degrees of soil structure, indicating that compaction has a significant potential for reducing the negative effects of slaking on earthquake resistivity.





### (3) Use of numerical analysis to assess the seismic resistance mechanism in a geotextile-reinforced soil

A seismic response analysis was performed on an embankment on the Noto Satoyama Kaido highway that had been rebuilt with geotextile reinforcement following its destruction in the Noto Peninsula Earthquake of 2007. The results gave clear evidence of the outstanding seismic-resistant capability of geotextile reinforcement.



(a) With geotextile reinforcement

Figure 4. Effect of geotextile reinforcement(Comparison of shear strain distributions immediately after an earthquake)

<sup>(</sup>b) Without geotextile reinforcement

## (4) Use of a soil-water coupled analysis for predicting the liquefaction-preventing effect of a pore water pressure dissipation method

A macro-element technique previously used only in vertical drain methods for the acceleration of consolidation, including vacuum consolidation, has now been integrated into the *GEOASIA* software and put to use in a numerical simulation of the pore water pressure dissipation method, one of the counter-technologies available for the prevention of liquefaction. The analysis was found to be capable of reproducing the controlling effect that the pore water pressure dissipation method has on declining shear rigidity through its offsetting reduction of effective stress, as well as its inhibiting effects on events such as lateral displacement and subsidence.



Figure 5. Excess pore water pressure distributions immediately after an earthquake

#### (5) Adaptation of a hyperelastic constitutive equation for inclusion in the SYS Cam-clay model

As a further refinement to the SYS Cam-clay model as the elastoplastic constitutive equation and driving motor of the *GEOASIA* analysis technology, the hyperelastic constitutive equation proposed by Einav and Puzin was inserted into it in a form adapted for finite transformations. Without any impairment to the basic working of the SYS Cam-clay model, an enhanced capability was thus obtained for the simulation of cyclic mobility in sand.



Figure 6. Repeated undrained shear strain responses (cyclic mobility) as represented by the SYS Cam-clay model adapted to include a constitutive equation for hyperelasticity

## (6) A soil-water-air coupled analysis of behaviors in an unsaturated embankment on a clayey soil foundation during construction and during and following an earthquake

A newly developed code for a coupled finite soil-water-air analysis of responses to static and dynamic external forces was used to simulate behaviors in an unsaturated embankment on a clay soil foundation during and after an earthquake. By this means it became possible to recreate a process in which enclosed saturation areas, originally formed inside the embankment at the construction stage as a result of compression settlement in the foundations, later underwent liquefaction on the occurrence of an earthquake. It was shown that rises and falls in water level would occur after the earthquake as a result of water flowing up from the foundations into the embankment.

(7) Inspection of evidence from the Great East Japan Earthquake of 2011 for the counter-deformation effects of ground improvement through compaction

An inspection was undertaken on a reclaimed ground in the Urayasu area for the effects of compaction methods of ground improvement under the impact of strong and sustained earth tremors. The response mechanisms were also investigated. The columns of dense sand resulting from the sand compaction pile method were found to be capable of withstanding the seismic stresses in the vicinity thanks to their rapid shearing in response to the earth movement and to their hardening as a result of plastic swelling (positive dilatancy). This indicates that ground improvement through compaction has a sufficient restraining effect on deformation even with earth tremors that persist for a considerable length of time.

### Principal publications etc. in Academic Year 2013 (including the first half of AY 2014)

#### Academic papers:

#### [Soils and Foundations]

- ① Acceleration generation due to strain localization of saturated clay specimen based on dynamic soil-water coupled finite deformation analysis, 53(5), pp.653-670, 2013.
- 2 A 3D soil-water coupled FE analysis of hollow cylinder test concerning non-uniform deformation, **53**(6), pp.923-936, 2013.
- ③ Realization of uniform deformation of soil specimen under undrained plane strain condition based on soil-water coupled finite deformation analysis considering inertia forces, 53(6), pp.937-950, 2013.
- [Geotechnical Engineering Journal of the SEAGS & AGSSEA]

Influence of brittle property of cement treated soil on undrained bearing capacity characteristics of the ground, 44(3), pp.84-93, 2013.

[Proceedings of the 10th Japan National Symposium on Environmental Geotechnology]

Consideration for Effective Utilization of Disaster Waste as Geomaterial, Vol.10, pp.385-390, 2013.

#### **International conferences:**

[The 15th Asian Regional Conference on Soil Mechanics and Geotechnical Engineering (Japan, Hukuoka, November 2015)]

- ① Riedel shear band formation with flower structures that develops at the surface ground on a strike slip fault.
- ② Interpretation of slaking of mudstone embankment based on soil skeleton structure and reproduction of the failure by seismic analysis.
- ③ Soil-water-air coupled seismic behavior accompanying internal water level variation of an unsaturated embankment with an enclosed saturated area on cohesive soil ground.
- ④ Proposal of a new double hardening elasto-plastic constitutive model of soil skeleton based on integration of associated and non-associated flow rules.
- 5 Liquefaction damage enhanced by interference between body wave and induced surface wave on inclined bedrock.
- 6 Evaluation of the improvement effects by vertical drains/vacuum consolidation on peaty ground under embankment loading.
- $\bigcirc$  New phase of particle method for geotechnical engineering.
- (8) Numerical simulation of pore water pressure dissipation method based on a soil-water coupled analysis enhanced by macro element method.
- (9) Seismic assessment of Nagoya Port Island against Nankai Trough earthquake.
- ① Air coupled effects on triaxial behavior of silty specimens under a constant confining pressure and various exhausted conditions.
- ① Geotechnical utilization of disaster waste soils.

[1st International Conference on Computational Engineering and Science for Safety and Environmental Problems, COMPSAFE 2014 (Japan, Sendai, April 2014)]

- ① Simulation of well resistance of vertical drains using a new macro-element method.
- ② Seismic response analysis of river embankments constructed on the alternatively layered soft ground.

[International Conference on Unsaturated Soils: Research & Applications, UNSAT2014 (Australia, Sydney, July 2014)]

- ① Verification of a new soil-water-air coupled analysis based on a rate-type equation of motion through realization of uniform deformation of an unsaturated soil specimen.
- 2 Numerical simulation of mechanical behavior of a triaxial silty soil under undrained and various controlled air boundary conditions.

[14th International Conference of the International Association for Computer Methods and Advances in Geomechanics, 14th IACMAG (Japan, Kyoto, September 2014)]

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- ① Numerical analysis of improvement effects on peaty ground by vertical drains/vacuum consolidation based on a new macro-element method.
- ② Soil-water coupled finite deformation analysis on subgrade reaction force acting on the underground pile.

③ Seismic assessment of river embankments with cut-off wall constructed on the alternatively layered soft ground.

#### **Domestic conferences:**

[68<sup>th</sup> Japan Society of Civil Engineers 2013Annual Meeting (Chiba, September 2013)] 2 papers.

[49<sup>h</sup> Japan National conference on Geotechnical Engineering (Kitakyushu, July 2014) ] 21 papers.

[26<sup>th</sup> Chubu Geotechnical Symposium (Nagoya, August 2014)] 3 papers.

[17<sup>th</sup>Symposium on Applied Mechanics(Okinawa, may, 2014)] 1paper

[Annual Meeting of the Chubu branch of Japan Society of Civil Engineers (Gifu, March, 2014)] 2papers

[1<sup>th</sup>Symposium on Levee Technologies Viewed from the Perspective of Geotechnical Engineering (Tokyo, November, 2013)] 2papers

[19thComputational Engineering Conference (Hiroshima, June, 2013)] 5papers

[From Overcoming the Great East Japan Earthquake: Special Symposium held by the Japanese Geotechnical Society (Tokyo, May, 2013)] 12papers

#### Japan Geoscience Union:

[Japan Geoscience Union Meeting 2014 (Makuhari, April, 2014)]

Liquefaction damage expansion caused by the generation of surface waves from base end section

2 Numerical simulation of shear bands formation in ground due to strike-slip fault

### Awards for Research using the GEOASIA Geotechnical Analysis Tool

[Japan Society of Civil Engineers Chubu Chapter, 2013 Technology Award]

Yoshikawa Takahiro, Noda Toshihiro, Kodaka Takeshi, Takaine Toshihiro: Soil-water-air coupled analysis on co- and post-seismic behavior of an unsaturated embankment on clayey soil ground

[Japanese Geotechnical Society Chubu Chapter, 2013 Academic Paper Award]

Yoshikawa Takahiro: Soil-water-air coupled finite deformation simulation of an unsaturated soil structure during construction and during/after a seismic motion

Best Paper Award in the 3rd International Conference on Geotechnique, Construction Materials and Environment (GEOMATE

2013) Mutsumi Tashiro, Toshihiro Noda, N. H. Son

[Nippon Expressway (NEXCO), Central Nippon Expressway Company, Letter of Thanks]

Proposal of countermeasures for the soft ground under embankment in the Mukasa area of the Maizuru-Wakasa Expressway

### Main Forthcoming Activities in 2014

The coming year 2014 will see continued activities in response to survey and research requests, the tasks of information supplying and technical instruction, and the development and dissemination of software. The fruits of this work will be presented at home and abroad to conferences in the fields of geomechanics, geotechnology, and seismology, and subsequently, in November 2015, to the 15<sup>th</sup> Asian Regional Conference on Soil Mechanics and Geotechnical Engineering in Fukuoka. Naturally, papers will also be contributed to journals. Opportunities will be sought for collaborative activities with academic societies, and extensive assistance will be offered with research and surveying work, putting to use the knowledge and insights obtained through the *GEOASIA* analysis tool. Efforts will also be continued to upgrade the constitutive equation to facilitate its use with an increasing diversity of soil types, including unsaturated and improved soils.

### **Editorial Afterword**

For the past few years, to judge from reactions to conference presentations in Japan and overseas, there has been a steady growth in interest for the *GEOASIA* analysis tool, and one of the Society's aims in 2014 will be to ensure a still wider diffusion of this technology, abroad as well as in Japan, through publicity activities centering on the Society's homepage, improvements to the technology itself, overseas patent applications, and a more systematic procedure for the processing of research requests. At the last general meeting of the Society, a further three *GEOASIA Master degree* were approved, bringing the running total to 16, including two international ones. In order to maintain this increase in the number of master awards, efforts will be continued in education and technical instruction. For all activities of the Society, we count on the ongoing support of our members.